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AGS Division Technical Note
No. 176

The "U" Line--1981

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Introduction

This technical note is an attempt to redocument the FEB transport line as beam sizes observed on "U" line flags do not compare well with the calculated beam sizes. Magnet locations were checked and compared with the locations in the FEB manual. Flags were removed and measured. In most cases new flags were reinstalled. Power supply and magnet information was obtained from the EAG magnetics section and compared with observed magnetic information. The beam pipe size was measured along the U line. The effects of the correction sextupole being at the wrong polarity and UQ8A being run at a very high current were studied.

Magnet and Power Supply Data

Figure 1a - 1e shows a printed output from the program QTUNE which lists the characteristics of the U line. A drawing of the beam line is shown in Figure 8. The magnet steel lengths were all measured. The effective lengths were obtained from the magnetics group or estimated. The magnet spacings were measured when possible and compared with the FEB manual. The trim magnets and new magnets were located. No major discrepancies were found between the FEB manual and the "U" line. Figure 1a-b shows the magnet effective lengths, locations, types and apertures. The flag locations are given. The power supply information is shown with the maximum power supply current. Figure 1c repeats some information in 1a - 1b and also gives the magnetic field data. This data is expressed as a power series and is valid for all currents from zero to the maximum magnet current listed. The quadrupole gradient data was obtained from excitation curves and the effective length. The dipole KG-IN information was obtained in a similar manner.

For example, a quad gradient is:

$$G = A_0 + A_1 I + A_2 I^2 + A_3 I^3 + A_4 I^4 \text{ kG/in}$$

with the current in kiloamps. The power series represents the data supplied within $\pm 0.4\%$ in most cases and $\pm 2\%$ in the worst case.

Figure 1d - 1e shows calculated information assuming the power supplies are at a given AGAST setting. The settings listed are also used for the groups of Figures 3 and 6. A negative command or readback corresponds to an AGAST "A" reading--213A is -213. The current and field information is calculated from the constants of Figure 1a - 1c. As the note in Figure 1e explains, the gain of the elements (GEL) is the bend angle of the dipoles or the gradient of the quads with the proper sign for a horizontal or vertical focusing quad. On Figure 1e, certain useful variables available on AGAST and calculated by the QTUNE program are defined. All AGAST names having a "%" character are parameters calculated by the program. Further information can be found on a paper on the "QTUNE" program.

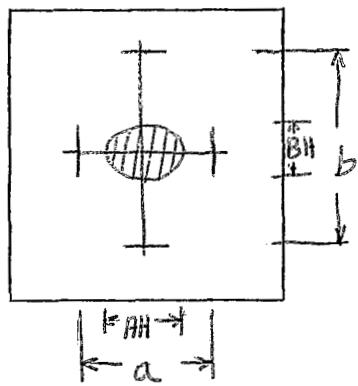
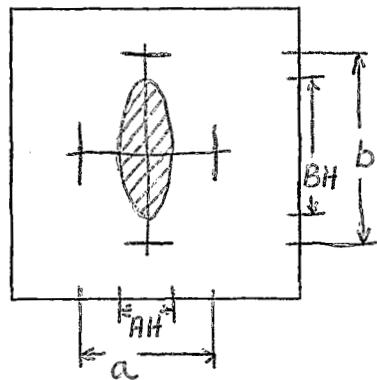
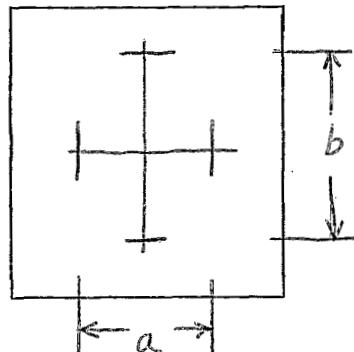
Figure 1f shows the location and power supply information for the "U" line trim magnets. The trim magnet information is not used to calculate beam sizes. All dipole or pitching trim magnets in the "U" line are 6.75D25 magnets. The constants for this magnet are:

A_0	= 0.09519696	Eff. length	= 30.75 inch
A_1	= 103.4235	Max. magnet current	= 0.60 kA
A_2	= -22.57931		
A_3	= 172.3323		
A_4	= -220.1772		

$$\text{KG-In} = A_0 + A_1 I + A_2 I^2 + A_3 I^3 \text{ for } I \text{ in kiloamps.}$$

The power supplies were calibrated in June 1981 by Joe LeLaidier, an EAG technician. The magnetic fields were measured in most magnets later in June, but at a different AGAST setting from Figure 1 with the Bell Gaussmeter. The probe was held next to the pole tips by Ken Reece. Using the AGAST CMD or RDBK that gave the most accurate power supply calibration, the magnetic fields were calculated in the "U" line magnets. The results are shown in Figure 2 using measured pole tip radii. For the sextupole US1A, the gradient dimensions are KG/in². The pole tip fields for UQ12, 13 and 14 were not measured because magnet covers or tight spaces prevented putting the probe in the magnet gap. Figure 2 shows large errors for UQ7, UQ8A and the correction sextupoles US1A and US1B.

Beam sizes in the FEB line can now be measured only from flag measurements. The flags are radelin that are mounted at a 45 degree angle so that a TV monitor may observe the beam striking the flag. Except for U799F all flags are tilted in the vertical plane. Flag U799F is tilted in the horizontal plane. To compensate for the tilt, the graticule spacing in the tilt plan is 1.41 times the effective spacing as observed on the TV monitor. All "U" line flags have been measured and most have been replaced with new flags. One flag was found to be mounted incorrectly in July 1981, so that the long dimension was not in the tilt plane. In most cases, the graticules appear about one inch apart on the TV so that a beam just touching all four marks would be a one inch by one inch beam. Some flags have holes and one flag has a hole and no marks. The following table shows the flags now (October 1981) and as they were in May-June 1981 and perhaps for several years before 1981. The flag 273F is located at 273 feet but is labelled on the flag as 303. It was necessary to use the shorter 303 instrument box in the 273 location when the replacement sextupoles were used near the 8 degree magnets.

U15F, U380FU165F, U273(303)U618F, U667F, U772F, U799F

	OLD DIMENSIONS				CURRENT DIMENSIONS			
	<u>Actual</u>		<u>On TV</u>		<u>Actual</u>		<u>On TV</u>	
	<u>a(AH)</u>	<u>b(BH)</u>	<u>a(AH)</u>	<u>b(BH)</u>	<u>a(AH)</u>	<u>b(BH)</u>	<u>a(AH)</u>	<u>b(BH)</u>
U15F	2.0	1.25	2.0	0.88	2.0	1.25	2.0	0.88
Hole U15F	1.31	0.63	1.31	0.44	1.31	0.63	1.31	0.44
U380F	1.0	1.42	1.0	1.0	1.02	1.41	1.02	1.0
Hole U380F	1.38	0.4	1.38	0.28	1.31	0.37	1.38	0.26
U165F	NO GRATICULES				NO GRATICULES			
Hole U165F	0.75	1.0	0.75	0.70	0.75	1.0	0.75	0.70
U273(303)	0.78	1.51	0.78	1.07	0.7	1.5	0.7	1.06
Hole U273(303)	0.47	1.69	0.47	1.20	0.44	1.62	0.44	1.15

(All Dimensions in Inches)

	OLD DIMENSIONS				CURRENT DIMENSIONS (10/81)			
	<u>Actual</u>		<u>On TV</u>		<u>Actual</u>		<u>On TV</u>	
	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>
U618F	1.4	1.0	1.4	0.7	1.0	1.38	1.0	0.98
U667F	1.02	1.35	1.02	0.96	1.0	1.25	1.0	0.88
U772F	1.0	1.38	1.0	0.98	1.0	1.38	1.0	0.98
U799F	1.37	1.0	0.97	1.0	1.38	1.0	0.98	1.0
U815F	NO GRATICULES - 0.625 DIA.				NO GRATICULES - 0.625 DIA.			

"U" Line Flag Dimensions

The best known input beam is used to calculate the beam widths in the U line. Weng's¹ input emittance for the new H5 extraction system is used with input momentum dispersion and input momentum spread in the horizontal plane. The emittances listed in the FEB manual, used by Weng, and used in the QTUNE program are listed on the next page.

H13 Input FEB Emittance

	<u>FEB Manual</u>	<u>Weng</u>	<u>QTUNE</u>
α_x =	-5.67	-5.67	-5.67
β_x =	5.746 cm/mrad	= 57.46 m/rad	= 2.62 in/mrad
ϵ_x =	0.12 cm-mrad(0.0472 in-mrad)		
ϵ_x =	--- 1.5×10^{-6} m-rad(0.5906 in-mrad)	= 0.006412 in-mrad rms	
$\Delta P/P$ =	---	$\pm 0.12\%$	$\pm 0.12\%$
X_p =	---	-2.96 m/ratio (-2.96 cm/%)	= -1.165 in/%
X_p^1 =		-295 mrad/ratio (-2.95 mrad/%)	= -2.95 mrad/%
α_y =	0.987	0.987	0.987
β_y =	3.7 m/rad	= 0.370 cm/mrad	= 0.1457 in/mrad
ϵ_y =	0.186 cm-mrad(0.0732 in-mrad)		
ϵ_y =	1.5×10^{-6} m-rad(0.0590 in-mrad)	= 0.006412 in-mrad rms	

Weng used a slightly different horizontal emittance from the FEB manual since he also included momentum spread and dispersion. Some beam sizes were first calculated using TRANSPORT to check the QTUNE program. The results compare very accurately. The QTUNE program was used to plot graphs since this program takes the information directly from an AGAST display. For historical reasons QTUNE uses the inch system and the rms emittance and plots beam sizes and make calculations for a 99% beam. The program also plots the momentum dispersion parameters along the beam line.

$$\epsilon \text{ (99% beam)} = -2 \ln (0.01) \epsilon_{\text{rms}} = 9.2103 \epsilon_{\text{rms}}$$

beam width (99% beam) = 3.0348 (beam width for rms beam).

Beam Size Results

The following discussion uses beam half sizes. Using the best known flag sizes, as measured by J.W. Glenn, the observed beam sizes were:

<u>Flag</u>	<u>Horizontal (inch)</u>	<u>Vertical (inch)</u>
U15	0.67	0.28
U165	?	0.70
U273	0.35	0.60
U380	1.0	0.60
U618	0.35	1.37
U667	0.28	1.15
U772	0.87	0.28
U799	0.25	0.60
U815	0.030	0.020

Figure 3a - 3c show the calculated beam sizes in the "U" line using the AGAST settings and field expansions of Figure 1. Printed below the curve on Figure 3a are the AGAST settings and the calculated parameters that are defined on Figure 1e. The observed beam sizes are marked as crosses. Figure 3a also shows the calculated value of the momentum dispersion parameters X_p and X'_p along the beam line. For clarity, these were left off Figures 3b and 3c. All curves are with the same AGAST settings of Figure 1. After the 8 degree magnet, the momentum dispersion parameters are:

$$X_p = 0.339 \text{ in}/\% \quad X'_p = -2.04 \text{ mr}/\%$$

These parameters are U8%MD and U8%MP. For a dispersionless line after these magnets, these values should both be zero. Weng¹ shows that it is necessary to change the beam line upstream of the 8 degree magnets to achieve this since the "U" line has initial momentum dispersion.

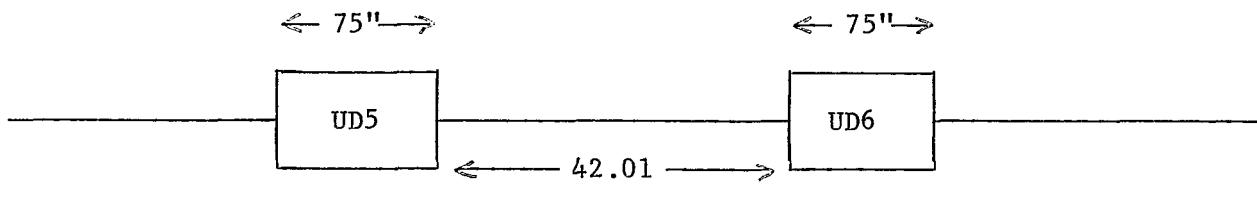
Figure 3 shows a large error between the calculated vertical half size and observed size in most of the beam line. The parameters TG%UH and TG%UV show that the calculated beam half sizes at the target are 0.256 and 0.076 inches which does not agree with the flag sizes. The cause for these errors is not known, but some possible causes were investigated.

Figure 4 and the following table show that small changes in UQ11-UQ14 will make the calculated beam small of the target. The small calculated beam of 52 by 25 mils is greater than the observed 30 by 20 mil beam.

Name	AGAST Start	AGAST Small Beam	Percent Change
UQ11	435B	514B	18.0
UQ12	2916A	2689A	- 7.8
UQ13	2746A	2511A	- 8.6
UQ14	1894B	1963B	3.6
Horiz. Half Size	0.257 inch	0.053 inch	
Vert. Half Size	0.076	0.025	

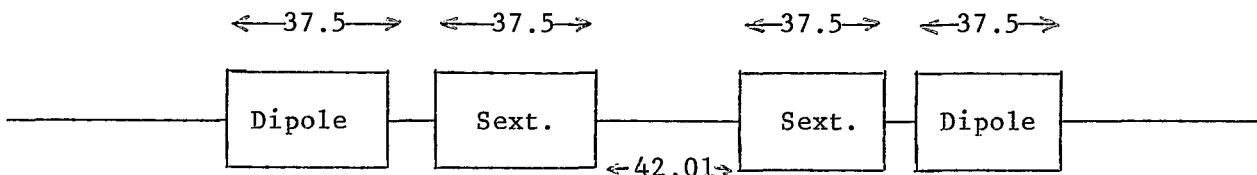
Sextupole Results

The effect of the correction sextupoles in the FEB line were investigated to try to explain the flag discrepancies. Second order TRANSPORT was used to determine sextupole effects. A simplification was made, as shown below, to separate the 8 degree dipole into a short dipole followed or preceded by a short sextupole. Both short magnets had double the actual magnetic field.



Dipole = 2581.008 KG-in	2581.008 KG-in
Dipole = 34.413 KG	34.413 KG
Sextupole = 1.731 KG	1.731 KG
Sextupole = 0.4328 KG/in ²	0.4328 KG/in ²
Sextupole Radius = 2.0 inch	

Actual Physical System



Dipole = 68.82688 KG	Dipole = 68.8268 KG
Sextupole = 3.4622 KG	Sextupole = 3.4622 KG

System Used for Transport

The sextupole field in the 8 degree magnet is not well known. The following table gives the fields in that magnet and the external shimmed sextupole US1A.

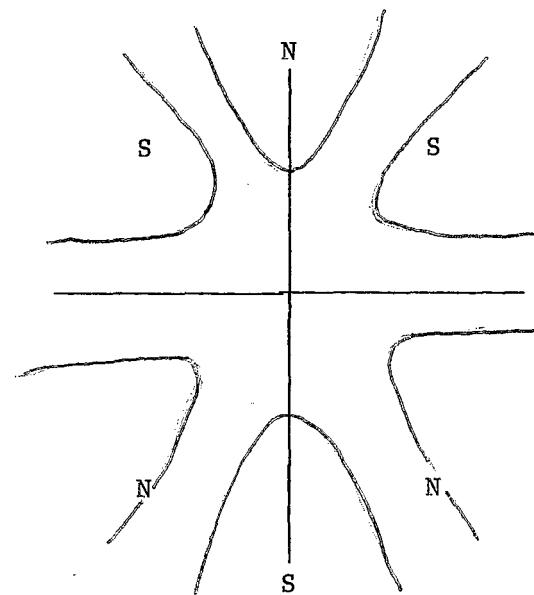
<u>8 Degree Correction Coil</u>	<u>External Shimmed Sextupole</u>
$A_0 = 0.00194$	0.13574
$A_1 = 2.317825$	1.3395
$A_2 = -0.040949$	0.66138
$A_3 = -0.35138$	-0.89414
$A_4 = \emptyset$	-0.243625
Effective Length = 75 inch	26.06 inch
Pole Tip Radius = 2.0 inch	2.063 inch

Sextupole Gradient Sx Table

The gradient can be found from:

$$S_x = A_0 + A_1 I + A_2 I^2 + A_3 I^3 + A_4 I^4 \text{ KG/in}^2 \text{ for } I \text{ in kiloamps.}$$

The 8 degree dipoles produce a sextupole error field that adds to the dipole field on the horizontal midplane. Since the dipoles have a field that is up to bend protons to the east, the equivalent sextupole is as shown



Equivalent Sextupole Produced by the 8 Degree Dipoles

TRANSPORT considers this sextupole a negative sextupole. The external and internal correction sextupoles must have the opposite polarity.

Figures 5a - 5b give the TRANSPORT data file for the external sextupoles at the correct polarity to cancel the dipole error field. The results of several computer runs are shown in Figure 6 for the beam line starting at the first correction sextupole upstream of the 8 degree magnets. The power supplies are set at the same value as in Figure 2. Curve 1 is a first order calculation or a second order calculation, with no sextupoles which also is the same as Figures 3a - c. Curve 2 shows the effect of shorter dipoles at twice the field and no sextupoles. Curve 3 assumes that the correction sextupoles are off but the dipole error sextupoles are on. Curves 4 and 5 show the correction sextupoles on at the correct and wrong polarities. It should be noted that curves 3-5 are valid for either polarity of the dipole error field. Curve 4 shows that the correction sextupoles do cancel the effect of the error field. The only difference occurs down near Q11 in the horizontal plan and this difference is less than 0.030 inches. These correction sextupoles are also at a field 12 percent too strong to cancel the dipole error as shown below:

$$S_x \propto \frac{\text{field}}{(\text{radius})^2} \times \text{length}$$

$$S_x = 32.46 \text{ KG/in for } 8^\circ \text{ error}$$

$$S_x = 36.34 \text{ KG/in for US1A}$$

The crosses show the measured beam sizes. It can be seen that if the correction sextupoles were at the wrong polarity, some vertical errors could be explained. However, the curves show that the horizontal beam would also blow up and this was not observed. One can conclude that the sextupoles were operating at the correct polarity.

Varying UQ8A

The quadrupole UQ8A is a vertical focusing quad that had a large error between calculated and measured gradients as shown in Figure 2. Figure 7 shows the effect of increasing the current in that magnet. For a current of 0.70 KA, the vertical beam fits inside the beam pipe and approaches the observed beam at 618F and 667F. This current, however, is 46 times the assumed current and

larger than the maximum current from AGAST for 4000 counts (0.25 KA). This current is, however, less an the magnet rating of 1.2 kA. This effect is not understood, but another possible cause could be the excitation of spare magnets existing in the U line. For example, UQ8B is 28.8 feet downstream of UQ8A and cables are connected to the coils of this magnet.

Conclusions

The errors or discrepancies of Figure 3 have not been satisfactorily explained. Magnetic field measurements should be repeated. The unused magnets should be checked to confirm that they are not energized. If the beam line information can be verified, a new H13 emittance may be needed to produce a calculated beam similar to the observed beam.

References

1. W.T. Weng, Momentum Dispersion of AGS Fast Extracted Beam, BNL 24658, April 1978.
2. W.T. Weng, The New AGS Fast Extraction System, BNL 51310, September 1980.

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SEFILE (BEAM FILE NUMBER; 1=A,2=B,3=C,4=D,5=U) 29.40
 PREAM (BEAM MOMENTUM, GEV/C)
 AREF13 (ALPHA, BETA (KILODINCH), EPSILON (INCH-MRAD, RMS) AT H13
 HORIZONTAL: -6.6358 2.2680 0.0078
 VERTICAL: 0.8708 0.1279 0.0095
 AGEH13 (ALPHA, BETA (KILODINCH), EPSILON (INCH-MRAD, RMS) AT H13
 HORIZONTAL: -5.6700 2.2620 0.0064
 VERTICAL: 0.9870 0.1457 0.0064
 DPP ((DELTA P/P) OR MOMEN.FRACT. IN % FDR 99% (U LN) BEAM) 0.1200
 H13MOM (INPUT HORZ. MOMEN. DISPERSION AT H13; INCH/Z, MR/Z) -1.1650 -2.9500
 TEKVER (=1 FOR TEKTRONIX PLOTS, =2(MODEL 1200) OR -2(MODEL 1100) VERSATEK & NO TUNING) 1
 LFRAME (=0 OR NEG. TO SUPPRESS FRAMES & LABELS ON GRAPHS;
 -1,0 OR 1 FOR ALL GRAPHS; -2 OR 2 FOR NO MOMEN.
 DISPERSION PLOTS) 2
 IACSGC (AGS FLAG; =1 FOR MAGNET VALUES FROM TTY, =2 FOR AGAST RDBKS, =3 FOR AGAST COMMANDS) 3
 PSTIME (POWER SUPPLY READ TIME IN MS AFTER IO) 1100
 ZRANGE (PLOTTING RANGE IN BEAM LINE FEET (MIN,MAX))
 0.000 (STARTING POINT OR 0 FEET FROM H13)
 10000.000 (END POINT OR END OF BEAM LINE) 1100
 IENUT (0="AGAST" OR TTY; -1 = OFFLINE "ENUTG") -1
 TEGFG (0=USE CURRENT "ENUTG" "RTUNX.TEG" FILE; -1 TO CHANGE FILE NAME) 0
 XYRANG (MAX. BEAM HALF SIZE FOR PLOTTING, INCH) 1.0000

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RMS PARAMETERS:
 ALPHA, BETA, EPSILON (H,V) AT H13: -5.6700 2.2620 0.0064 0.9870 0.1457 0.0064
 UD1 (-2727) UD2 (-3235) UD1-3(-2998) UD1-3(-2998) UD1-3(-2998) UD3-6(-2845) UD3-6(-2845) UD3-6(-2845) UD7 (-1727)
 5-6(-3847) UD5-6(-3847) UD8-9(-3534) UD8A (-240) UD8-9(-3534) UD10 (-1845) UD11 (-435) UD12 (-2916) UD13 (-2746) UD14 (-1894)
 UDZMD UDZMP UTZHZ UTZHX UTZVZ UTZVX TGZUH TGZUV
 339.76 -2040.37 -133.88 31.04 30.02 24.62 256.90 76.09

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"U" LINE MAGNETS FROM H13 TO U TARGET

---ELEMENT-- * NAME	---MAGNET----- * LABEL	KIND	GROUP	Z(U/S) INCH	LENGTH INCH	XAPER INCH	YAPER INCH	POWER SUPPLY INFORMATION				
								--PRIMARY----	MAX-	-SECONDARY-		
								DDF	AMPS/DCN	KAMPS	DDF	AMPS/DCN
10434 5 6 8	15F	DRIFT	0	0.000	120.000	1.800	1.800					
		DRIFT	0	120.000	72.320	1.440	1.440					
		DRIFT	0	192.320	0.001	0.000	0.000					
		DRIFT	0	192.321	17.249	1.440	1.440					
UD1	UD1	QUAD	N3Q3A	1	211.570	37.500	1.440	1.440	UD1	0.7500	2.400	
UD2	UD2	QUAD	N3Q34	1	249.070	19.500	1.440	1.440	UD2	0.6250	2.300	
		DRIFT	0	306.070	18.800	1.440	1.440					

Figure 1 a

9	UD1	UD1	RDPOL	4D78	11	324.870	81.900	1.940	1.440	UD1-3	1.0000	3.300
10	UD2	UD2	RDPOL	4D78	11	424.868	81.900	1.940	1.440	UD1-3	1.0000	3.300
11	UD3	UD3	RDPOL	4D78	11	524.866	81.900	1.940	1.440	UD1-3	1.0000	3.300
12	UD3	UD3	DRIFT		10	624.864	81.900	1.940	1.440			
13	UD3	UD3	DRIFT		10	724.864	81.900	1.940	1.440			
14	UD3	UD3	QUAD	4Q26	16	1230.646	28.598	1.690	1.690	UD3-6	0.0750	0.400
15	UD3	UD3	DRIFT		10	1259.244	40.000	1.690	1.690			
16	UD3	UD3	DRIFT		10	1289.244	232.260	1.690	1.690			
17	UD4	UD4	QUAD	4Q26	16	1532.204	28.598	1.690	1.690	UD3-6	-0.0750	0.400
18	UD4	UD4	DRIFT		10	1560.802	200.000	1.690	1.690			
19	UD4	UD4	DRIFT		10	1760.802	72.960	1.690	1.690			
20	UD5	UD5	QUAD	4Q26	16	1838.782	28.598	1.690	1.690	UD3-6	-0.0750	0.400
21	UD5	UD5	DRIFT		10	1868.380	111.500	1.690	1.690			
22	165F	165F	DRIFT		10	1978.880	0.001	0.000	0.000			
23	UD6	UD6	DRIFT		10	1978.881	141.458	0.490	0.490			
24	UD6	UD6	QUAD	4Q26	16	2135.819	28.598	1.690	1.690	UD3-6	0.0750	0.400
25	UD6	UD6	DRIFT		10	2163.917	272.960	1.690	1.690			
26	UD7	UD7	QUAD	4Q26	16	2424.877	28.598	1.690	1.690	UD7	-0.0750	0.300
27	UD7	UD7	DRIFT		10	2465.475	309.080	1.690	1.690		-0.100	
28	273F	273F	DRIFT		10	3274.560	0.001	0.000	0.000			
29	UD5	UD5	RDPOL	35C72	19	3370.060	75.000	1.940	1.940	UD5-6	0.2500	1.000
30	UD5	UD5	DRIFT		10	36445.060	87.000	1.940	1.940			
31	UD6	UD6	RDPOL	35C72	19	3487.070	75.000	1.940	1.940	UD5-6	0.2500	1.000
32	UD6	UD6	DRIFT		10	35562.070	141.458	1.940	1.940			
33	UD8	UD8	QUAD	4Q26	16	3677.700	28.598	1.690	1.690	UD8-9	-0.0625	0.250
34	UD8	UD8	DRIFT		10	3706.298	68.000	1.690	1.690			
35	UD8A	UD8A	DRIFT		10	3774.298	121.950	1.690	1.690			
36	UD8A	UD8A	QUAD	6Q16P	17	3896.248	20.000	0.690	0.690	UD8A	0.0625	0.250
37	360F	360F	DRIFT		10	3916.248	657.362	0.690	0.690			
38	UD9	UD9	DRIFT		10	4573.610	0.001	0.000	0.000			
39	UD9	UD9	QUAD	4Q26	16	4669.060	979.528	1.690	1.690	UD8-9	0.0625	0.250
40	UD9	UD9	DRIFT		10	4697.658	1081.260	1.690	1.690			
41	UD10	UD10	QUAD	4Q26	16	5778.918	28.598	1.690	1.690	UD10	0.1000	0.388
42	UD10	UD10	DRIFT		10	5807.514	1608.484	1.690	1.690			
43	618F	618F	DRIFT		10	7416.000	0.001	0.000	0.000			
44	667F	667F	DRIFT		10	7416.001	591.189	1.690	1.690			
45	UD11	UD11	DRIFT		10	8007.170	0.001	0.000	0.000			
46	UD11	UD11	QUAD	4Q26	16	8007.171	84.290	1.690	1.690			
47	772F	772F	DRIFT		10	8119.969	1115.302	1.690	1.690			
48	UD12	UD12	QUAD	8Q32P	18	9307.771	36.000	0.740	0.740	UD12	0.3750	1.200
49	UD12	UD12	DRIFT		10	9343.771	6.740	0.740	0.740			
50	UD13	UD13	QUAD	8Q32P	18	9350.511	36.000	0.740	0.740	UD13	0.3750	1.200
51	UD13	UD13	DRIFT		10	9386.511	105.510	0.740	0.740			
52	UD14	UD14	QUAD	N3Q36	18	9492.021	37.500	1.440	1.440	UD14	0.7500	2.400
53	UD14	UD14	DRIFT		10	9529.521	242.150	1.440	1.440			
54	S15F	S15F	DRIFT		10	9771.671	0.001	0.000	0.000			
55	UTGT	UTGT	DRIFT		10	9771.672	11.000	1.440	1.440			
56	UTGT	UTGT	DRIFT		10	9702.672	0.000	0.000	0.000			

"U" LINE MAGNETS FROM H13 TO U TARGET

ELEMENT NAME	LABEL	MAGNET KIND	GROUP	EFF. LEN INCH	KG/IN OR KG-IN POWER SERIES COEFFICIENTS FOR I IN KILOAMPS					MAX. MAGNET KAMPS		
					A0	A1	A2	A3	A4			
		DRIFT		0	120.000							
		DRIFT		0	72.320							
		DRIFT		0	0.001							
		DRIFT		0	19.249							
	UQ1	UQ1	QUAD	N3036	1	57.500	1.5201630E-02	4.4772430E+00	1.9772940E-01	4.7379500E-02	-9.1596540E-02	2.600
		DRIFT		0	19.500							
	UQ2	UQ2	QUAD	N3036	1	57.500	1.5201630E-02	4.4772430E+00	1.9772940E-01	4.7379500E-02	-9.1596540E-02	2.600
		DRIFT		0	18.800							
	UD1	UD1	RDPOL	4D78	11	81.900	2.6068880E-01	3.2376880E+02	9.2981530E-01	-3.0072490E-01	0.0000000E+00	3.400
		DRIFT		0	18.098							
	UD2	UD2	RDPOL	4D78	11	81.900	2.6068880E-01	3.2376880E+02	9.2981530E-01	-3.0072490E-01	0.0000000E+00	3.400
		DRIFT		0	18.098							
	UD3	UD3	RDPOL	4D78	11	81.900	2.6068880E-01	3.2376880E+02	9.2981530E-01	-3.0072490E-01	0.0000000E+00	3.400
		DRIFT		0	528.000							
		DRIFT		0	75.880							
	UQ3	UQ3	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	40.000							
	UQ4	UQ4	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	200.000							
	UQ5	UQ5	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	72.960							
	145F		DRIFT		0	111.500						
		DRIFT		0	0.001							
	UQ6	UQ6	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	272.960							
	UQ7	UQ7	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	809.085							
	273F		DRIFT		0	0.001						
		DRIFT		0	95.499							
	UD5	UD5	RDPOL	3SC72	19	75.000	-9.1349790E+00	3.2169220E+03	-3.5253800E+01	-5.2960020E+02	0.0000000E+00	1.100
		DRIFT		0	42.010							
	UD6	UD6	RDPOL	3SC72	19	75.000	-9.1349790E+00	3.2169220E+03	-3.5253800E+01	-5.2960020E+02	0.0000000E+00	1.100
		DRIFT		0	115.680							
	UQ8	UQ8	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	68.000							
		DRIFT		0	121.950							
	UQ8A	UQ8A	QUAD	8Q16P	17	20.000	-1.2346600E-03	2.5374630E+00	-1.5826770E-01	1.0157320E-01	0.0000000E+00	1.200
		DRIFT		0	657.382							
	380F		DRIFT		0	0.001						
		DRIFT		0	95.449							
	UQ9	UQ9	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	1081.260							
	UQ10	UQ10	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	1608.484							
	618F		DRIFT		0	0.001						
		DRIFT		0	591.169							
	667F		DRIFT		0	0.001						
		DRIFT		0	84.200							
	UQ11	UQ11	QUAD	4Q26	16	28.598	7.8877510E-03	9.2529370E+00	2.4783180E+00	-8.1294770E+00	-6.7577510E+00	0.550
		DRIFT		0	1155.302							
	772F		DRIFT		0	0.001						
		DRIFT		0	16.730							

55	UQ12	UQ12	DRIFT	0	15.769							
56	UQ12	UQ12	QUAD	8032P	18	36.000	-1.2346600E-03	2.5374830E+00	-1.5826770E-01	1.0157320E-01	0.0000000E+00	1.200
57	UQ12	UQ12	DRIFT	0	6.740							
58	UQ13	UQ13	QUAD	8032P	18	36.000	-1.2346600E-03	2.5374830E+00	-1.5826770E-01	1.0157320E-01	0.0000000E+00	1.200
59	UQ13	UQ13	DRIFT	0	105.510							
60	UQ14	UQ14	QUAD	N8036	1	37.500	1.5201630E-02	4.4772430E+00	1.9792940E-01	4.7379500E-02	-9.1596540E-02	2.600
61	UQ14	UQ14	DRIFT	0	242.150							
62	815F	815F	DRIFT	0	0.001							
63	815F	815F	DRIFT	0	11.000							
64	UTGT	UTGT	DRIFT	0	0.000							

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"U" LINE MAGNETS FROM H13 TO U TARGET

ELEMENT NAME	LABEL	MAGNET KIND	POWER SUPPLY DATA		MAGNET DATA FOR 29,400 GEV/C		
			DDF1 CMD/RDBK	DDF2 CMD/RDBK	CURRENT(KA)	KG-IN OR KG/IM	GAIN(GEL)

1.0400	15F	DRIFT					0.0	
1.0400	15F	DRIFT					0.0	
1.0400	15F	DRIFT					0.0	
1.0400	UD1	QUAD	UD1	-2727	0	2.04525	-8.8028	-8.80283
1.0400	UD2	QUAD	UD2	3235	0	2.02187	8.7376	8.73765
1.0400	UD1	RDPOL	UD1-3	2998	0	2.99800	971.1733	1.44121
1.0400	UD2	RDPOL	UD1-3	2998	0	2.99800	971.1733	1.44121
1.0400	UD3	RDPOL	UD1-3	2998	0	2.99800	971.1733	1.44121
1.0400	UD3	DRIFT					0.0	
1.0400	UD3	DRIFT					0.0	
1.0400	UD3	DRIFT					0.0	
1.0400	UD3	QUAD	UD3-6	-2845	0	0.21338	-2.0021	-2.00208
1.0400	UD4	QUAD	UD3-6	-2845	0	0.21338	2.0021	2.00208
1.0400	UD5	QUAD	UD3-6	-2845	0	0.21338	2.0021	2.00208
1.0400	165F	DRIFT					0.0	
1.0400	UD6	QUAD	UD3-6	-2845	0	0.21338	-2.0021	-2.00208
1.0400	UD7	QUAD	UD7	1727	0	0.12953	-1.2284	-1.22839
1.0400	273F	DRIFT					0.0	
1.0400	UD5	RDPOL	UD5-6	3847	0	0.96175	2581.0078	3.83019
1.0400	UD6	RDPOL	UD5-6	3847	0	0.96175	2581.0078	3.83019
1.0400	UD6	DRIFT					0.0	
1.0400	UD8	QUAD	UD8-9	-3534	0	0.22088	2.0689	2.06885
1.0400	UD8A	QUAD	UD8A	240	0	0.01500	0.0368	0.03679
1.0400	UD8A	DRIFT					0.0	

Figure 1 d

41	380F	DRIFT					0.0
42		DRIFT					0.0
43	UQ9	QUAD	UQ8-9	-3534	0	0.22088	-2.06889
44		DRIFT					0.0
45	UQ10	QUAD	UQ10	1345	0	0.13450	1.27525
46		DRIFT					0.0
47	418F	DRIFT					0.0
48		DRIFT					0.0
49	467F	DRIFT					0.0
50		DRIFT					0.0
51	UQ11	QUAD	UQ11	435	0	0.04350	0.41439
52		DRIFT					0.0
53	772F	DRIFT					0.0
54		DRIFT					0.0
55	UQ12	QUAD	UQ12	-2916	0	1.09350	-2.71707
56		DRIFT					0.0
57	UQ13	QUAD	UQ13	-2746	0	1.02975	-2.55482
58		DRIFT					0.0
59	UQ14	QUAD	UQ14	1694	0	1.42050	6.53737
60		DRIFT					0.0
61	615F	DRIFT					0.0
62		DRIFT					0.0
63	UTGT	DRIFT					0.0
64							0.0

NOTE *****

- A) CMD/RDBK -- READINGS ARE FROM EMUTR PGM. THE "A" RDBK IS NEGATIVE -- IE, 2140A = -2140.
- B) DDF2 (SECONDARY P.S. READBACKS) ARE NOT SAME RDBKS BUT READINGS OF TRIM P.S.
- C) KGIN -- KG/IN FOR QUADS; KG-IN FOR DIPOLES & ONLY APPROX. FOR DIPOLES WITH TRIM SUPPLIES.
- D) GEL -- = 0 FOR DRIFT; -KG/IN FOR H.F. QUAD; +KG/IN FOR V.F. QUAD; BEND ANGLE (DEGREES) FOR DIPOLES (+ = EAST).

NAME(??Z??)	AREA(FEB)	COMP()	DEVTYPE()	ADDR()	WHO()	WHR()	22-OCT-81
DEFINITION							
1	TCZUM	FEB	(REFERENCE)		(CALCULATED HORIZ. HALF WIDTH BEAM SIZE IN MILS AT U TGT. - QTUNE PGM)		
2	TCZUV	FEB	(REFERENCE)		(CALCULATED VERT. HALF WIDTH BEAM SIZE IN MILS AT U TGT. - QTUNE PGM)		
3	UQZMD	FEB	(REFERENCE)		(1000 X CALC. MOMENT. DISPERSION(CINCH/RATIO) AT END OF 8 DEG. MAGNET.)		
4	UQZMP	FEB	(REFERENCE)		(1000 X CALC. MOMENT. DISPERSION PRIME(MR/RATIO) AT END OF 8 DEG. MAG)		
5	UTZXH	FEB	(REFERENCE)		(HALF WIDTH(MILS) OF HORIZ. BEAM AT WAIST NEAR TGT. - QTUNE PGM. USES)		
6	UTZHZ	FEB	(REFERENCE)		(Z POS. OF U TGT. HORIZ. WAIST, INCH, 0=U TGT, -50=50 IN. UPSTRM U TG)		
7	UTZVX	FEB	(REFERENCE)		(HALF WIDTH(MILS) OF VERT. BEAM AT WAIST NEAR TGT. - QTUNE PGM. USES)		
8	UTZVZ	FEB	(REFERENCE)		(Z POS. OF U TGT. VERT. WAIST, INCH, 0=U TGT, -50=50 IN. UPSTRM U TG)		

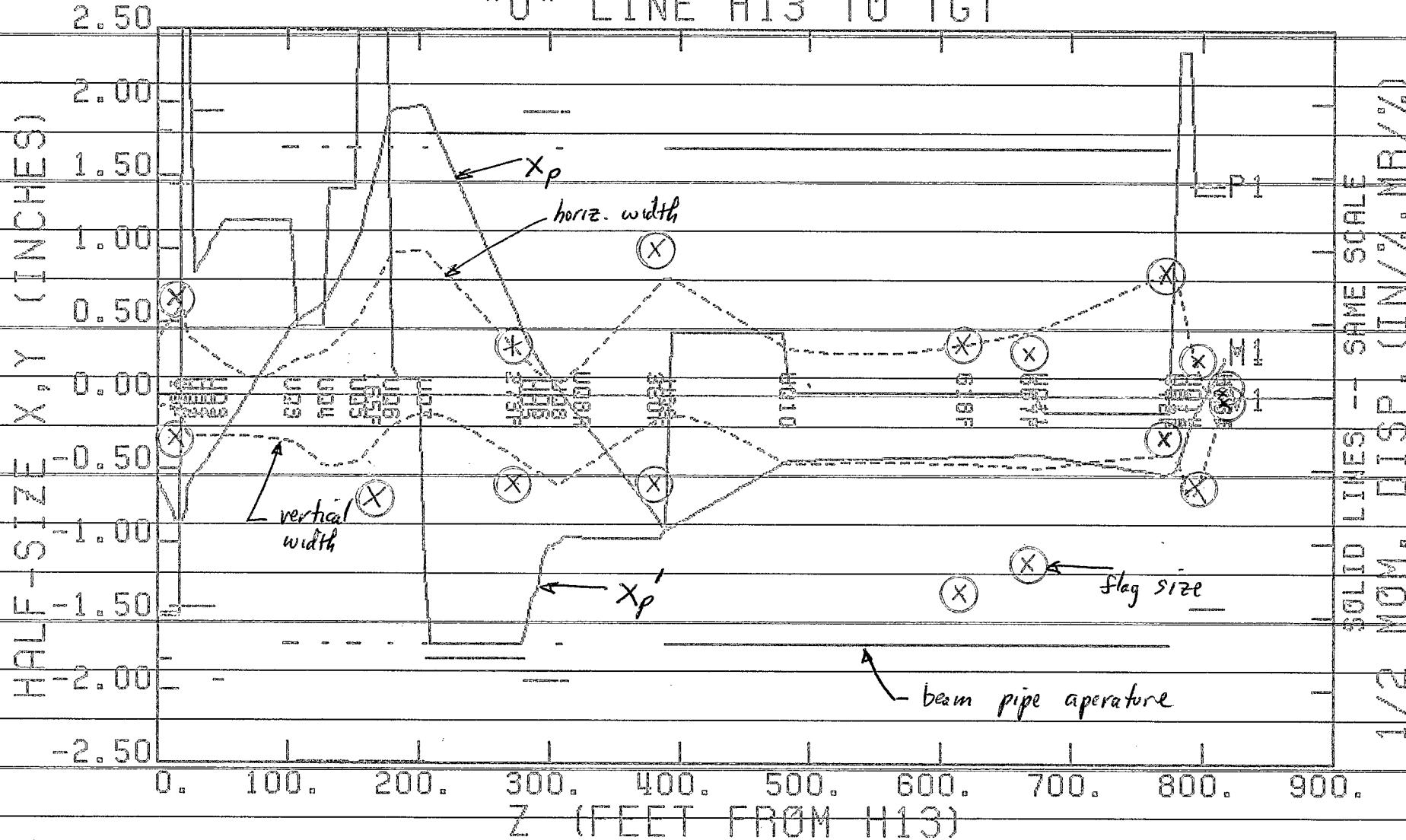
Figure 1 e

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"U" LINE TRIM MAGNETS FROM H13 TO U TARGET

ELEMENT # NAME	MAGNET KIND	GROUP	Z (U/S) INCH	LENGTH INCH	XAPER INCH	YAPER INCH	POWER SUPPLY INFORMATION			
							PRIMARY DDF	MAX AMPS/DCN	SECONDARY AMPS	MAX AMPS/DCN
2A UP1	DRIFT		0.00	95.945						
2B	WDPOL	6.75D24	95.945	30.75			UP1	0.10	0.388	
2C	DRIFT		128.695	84.875						
3 UQ1	QUAD	N3036	211.57	37.5			UQ1	0.75	2.4	
5A	DRIFT		249.07							
16 UQ3	QUAD	4026	1230.646	28.6			UQ3-6	0.0750	0.400	
17A	DRIFT		1259.246	9.575						
17B UP2	WDPOL	6.75D24	1268.821	30.75			UP2	0.10	0.388	
17C	DRIFT		1299.571	232.635						
19 UQ4	QUAD	4026	1532.204	28.6			UQ3-6	-0.0750	0.400	
20A	DRIFT		1560.804	218.635						
20B UD4	WDPOL	6.75D24	1779.439	30.75			UD4	0.10	0.388	
20C	DRIFT		1810.169	23.575						
22 UQ5	QUAD	4026	1833.762	28.6			UQ3-6	-0.0750	0.400	
36 UQ8	QUAD	4026	3677.70	28.6			UQ8-9	-0.0625	0.250	
37A	DRIFT		3706.30	21.575						
37B UP3	WDPOL	6.75D24	3727.875	30.75			UP3	0.10	0.388	
37C	DRIFT		3758.625	137.625						
39 UQ8A	QUAD	8016P	3896.248	20.0			UQ8A	0.0625	0.250	
40A	DRIFT		3916.248	346.0						
40B UQ8B	QUAD	8016P	4262.248	20.0						
40C	DRIFT		4202.248	386.812						
43 UQ9	QUAD	4026	4669.060	28.6			UQ8-9	0.0625	0.250	
44A	DRIFT		4697.86	118.575						
44B UD4A	WDPOL	6.75D24	4816.238	30.75			UD4A	0.10	0.388	
44C	DRIFT		4846.988	931.930						
45 UQ10	QUAD	4026	5778.918	28.6			UQ10	0.1000	0.388	
58 UQ13	QUAD	8032P	9250.511	36.0			UQ13	0.3750	1.200	
59A	DRIFT		9306.511	22.415						
59B UD7	WDPOL	6.75D24	9408.939	30.75			UD7	0.100	0.388	
59C	DRIFT		9439.679	7.745						
60 UP4	WDPOL	6.75D24	9438.934	30.75			UP4	0.100	0.388	
60E UQ14	DRIFT		9469.684	22.425			UQ14	0.7500	2.400	
	QUAD	N3036	9492.012	37.5						

"U" LINE H13 TO TGT



$$P = 29.4 \text{ GeV/c} \quad DPP = DP/p = \pm 0.12\% \quad H13 \text{ mom} = -1.165 \text{ m/r}, -2.85 \text{ m/r}$$

RMS PARAMETERS:

ALPHA, BETA, EPSILON (H,V) AT H13: -5.6700 2.2620 0.0064 0.9870 0.1457 0.0064

Q1 (-2727) Q2 (-3235) UD1-3(-2998) UD1-3(-2998) UD1-3(-2998) UQ3-6(-2845) UQ3-6(-2845) UQ3-6(-2845) UQ3-6(-2845) UQ7 (-1727)
 6-6 (-3647) UD5-6(-3647) UQ8-9(-3534) UQ8A (-240) UQ8-9(-3534) UG10 (-1345) UG11 (-435) UG12 (-2916) UG13 (-2746) UG14 (-1894)
 UXMD U8XHP UTXHZ UTXHZ UTXHZ UTXHZ TGXUH TGXUH
 339.76 -2049.37 -133.88 31.04 30.02 24.62 256.90 76.09

FIGURE 3 a

"U" LINE H13 TO TGT

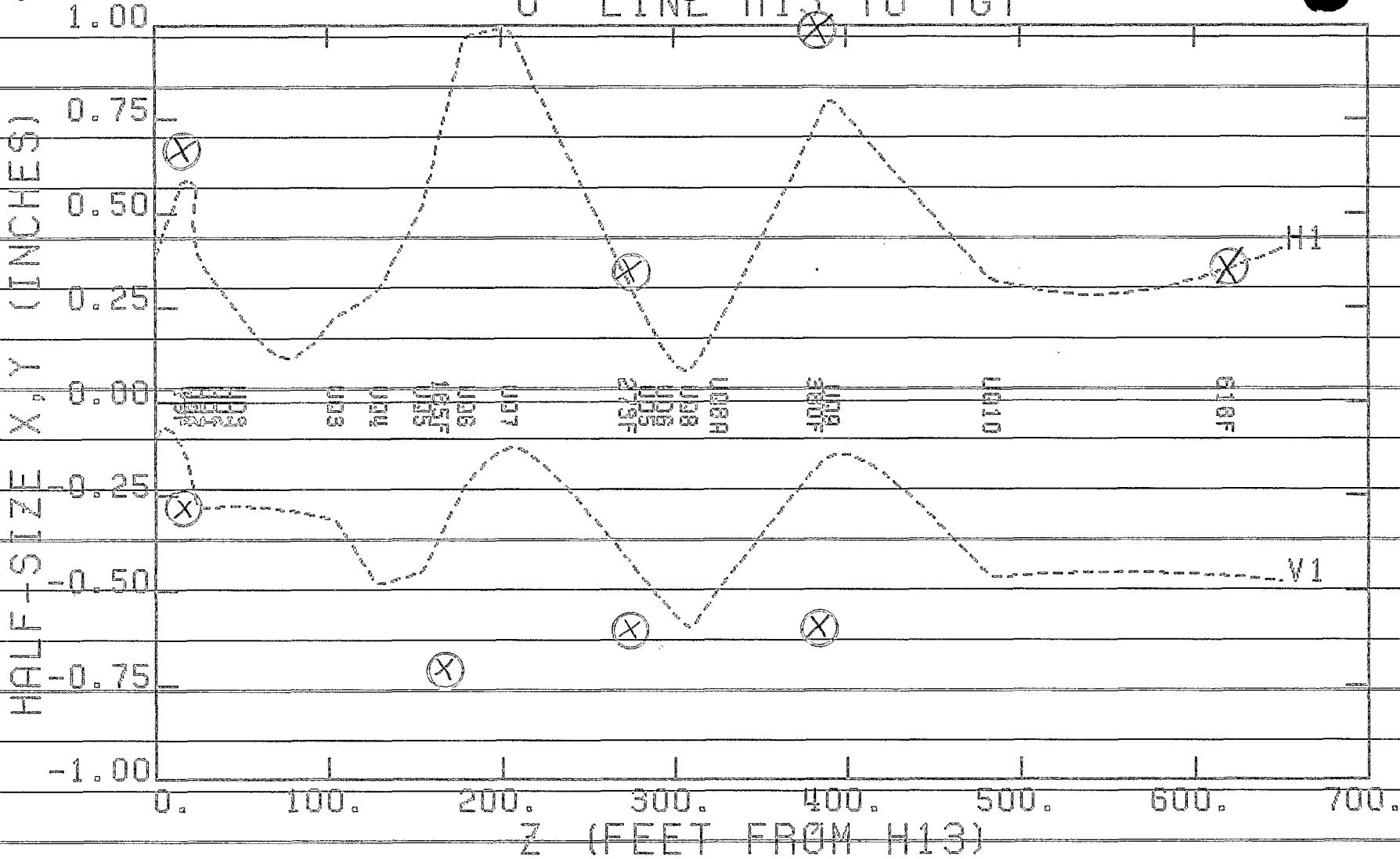


Figure 3 b

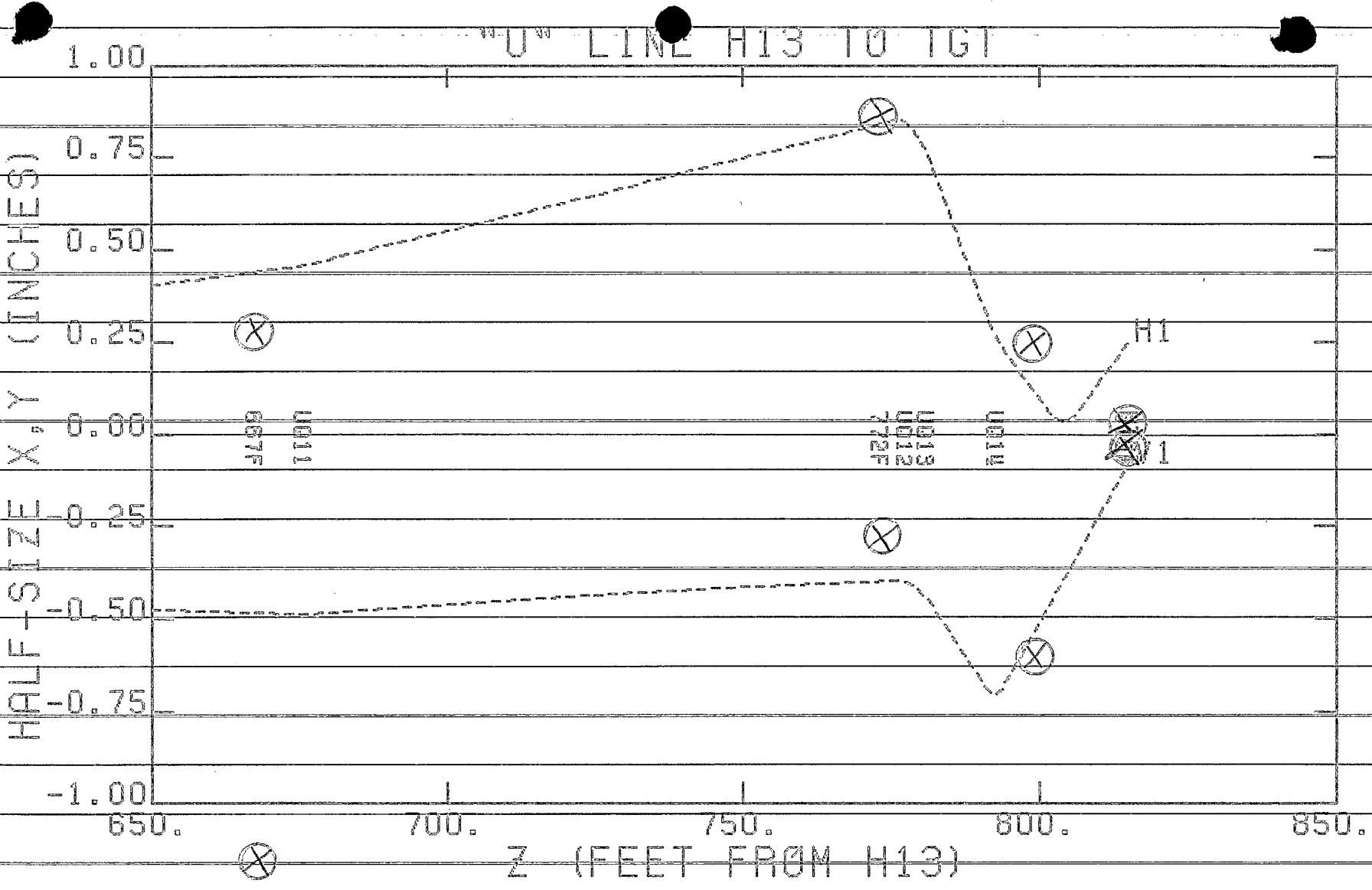
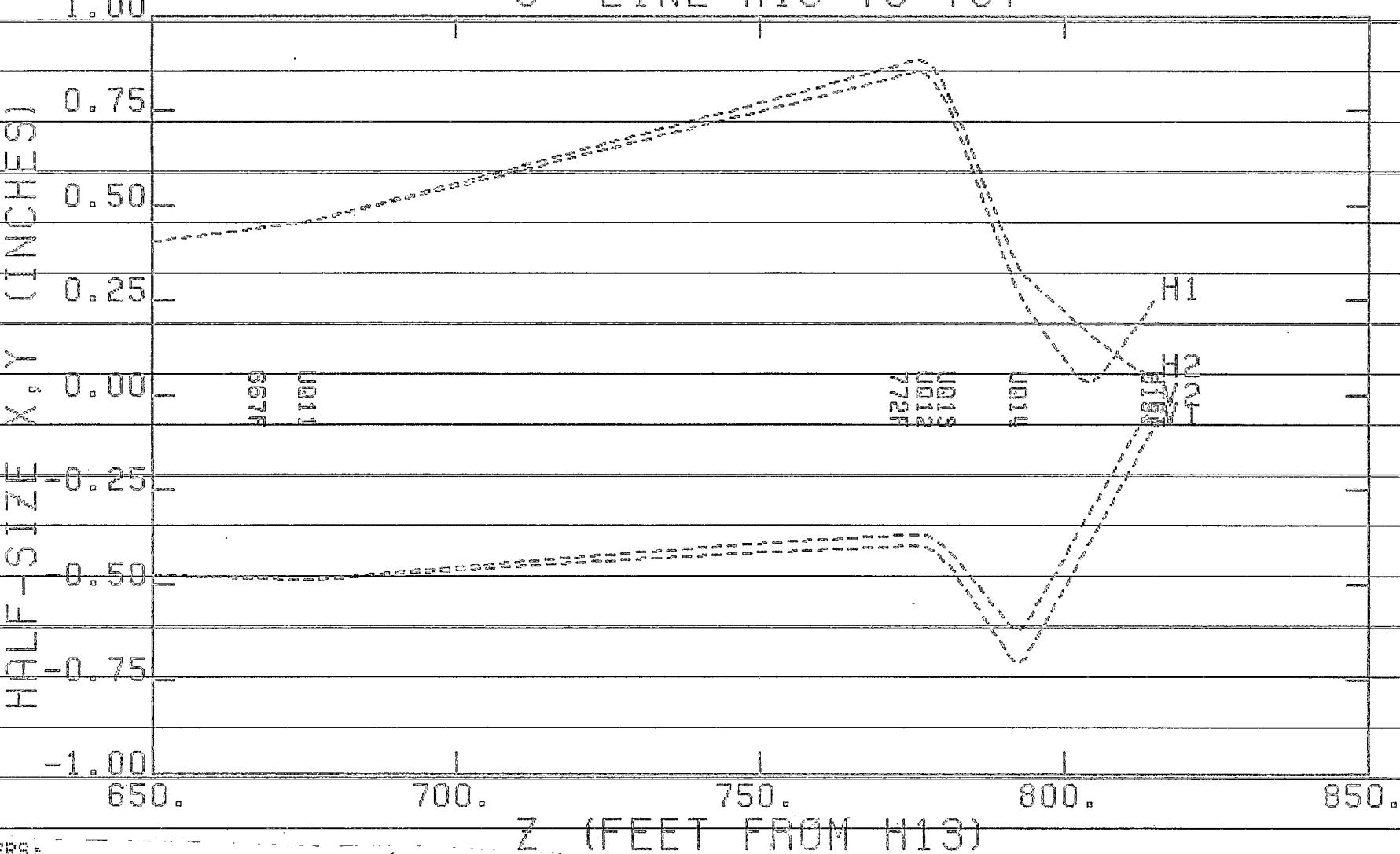


Figure 3 c

"U" LINE H13 TO TGT



RMS PARAMETERS:

ALPHA, BETA, EPSILON (H,V) AT H13: -5.6700 2.2620 0.0064 0.9870 0.1457 0.0064

U01 (-2727) U02 (-3235) U03-3(-2998) U03-3(-2998) U03-6(-2845) U03-6(-2845) U03-6(-2845) U07 (-1727)
 U08-6(-3847) U08-8(-3534) U08A (-240) U08-9(-3534) U010 (-1345) U011 (-435) U012 (-2916) U013 (-2746) U014 (-1994)
 U08MD U08MP UTXHZ UTXHZ UTXVZ UTXVX TGZUH TGZUV
 339.76 -2040.37 -133.88 31.04 30.02 24.62 256.90 76.09

RMS PARAMETERS:

ALPHA, BETA, EPSILON (H,V) AT H13: -5.6700 2.2620 0.0064 0.9870 0.1457 0.0064

U01 (-2727) U02 (-3235) U03-3(-2998) U03-3(-2998) U03-6(-2845) U03-6(-2845) U03-6(-2845) U07 (-1727)
 U08-6(-3847) U08-8(-3534) U08A (-240) U08-9(-3534) U010 (-1345) U011 (-514) U012 (-2689) U013 (-2511) U014 (-1963)
 U08MD U08RP UTXHZ UTXHZ UTXVZ UTXVX TGZUH TGZUV
 339.76 -2040.37 -1.24 49.22 0.30 25.24 52.78 25.25

Figure 4

" U LINE - H13 THRU UTGT --H13 MOM. DISP & SEXTUPOLES ADDED"
 CHANGE TO INCHES FOR MAGNET SIZES & THOUSAND INCH LENGTH)
 1. "IN" 2.54;
 3. "KIN" 25.4;
 4. "H13" .365505 .930326 .092763 .894559 0.0 0.12 29.4;
 (FOR SECOND ORDER CALC.)
 12. "H13" .984801 0.0 0.0 0.0 -.7024655;
 13. 2.
 13. 0.0;
 13. 4.
 (UPDATE R1 & R2 MATRIX & ADD H5 DISPERSION)
 14. 1. 0. 0. 0. 0. -1.165 1.
 14. 0. 1. 0. 0. 0. -2.95 2.
 14. 1.
 14. 0.0;
 MATRIX ELEM. DIMENSIONS: R16 = INCH/%, R26= MR/%)
 0.21157;
 "UQ1" .0375 0.80283 1.;
 0.0195;
 "UQ2" .0375 -0.73765 1.;
 0.0188;
 (UD1-3 WITH POLEFACE ROTATION, EACH BEND = 1.4156 DEG)
 2. .7077 4. "UD1" 0.0819 11.85804 0.0; 2. 0.7077;
 0.018098;
 0.7077 4. "UD2" 0.0819 11.85804 0.0; 2. 0.7077;
 0.018098;
 0.7077 4. "UD3" .0819 11.85804 0.0; 2. 0.7077;
 0.300;
 0.32388;
 "UQ3" 0.0286 2.00208 1.;
 0.27296;
 "UQ4" 0.0286 -2.00208 1.;
 0.27296;
 "UQ5" 0.0286 -2.00208 1.;
 0.27296;
 "UQ6" 0.0286 2.00208 1.;
 0.27296;
 "UQ7" 0.0286 1.22839 1.;
 3.
 0.45806;
 0.400;
 18. "S1A" .02606 5.9342 2.063;
 3. 0.02047;
 (UD5-6 WITH POLEFACE ROTATION, BEND=4.00 DEG)
 2. 2.00 4. "UD5" 0.0375 46.82688 0.0; 2. 2.00;
 18. "UDSX" 0.0375 -3.4622 2.0;
 3. 0.04201;
 18. "UDSX" 0.0375 -3.4622 2.0;
 2. 2.00 4. "UD6" 0.0375 46.82688 0.0; 2. 2.00;
 3. 0.02648;
 18. "S1B" .02606 5.9342 2.063;
 3. 0.04310;
 "UD8" .0286 -2.06885 1.0;
 3. 18995;
 (UBBA ONLY VERT. FOCUSING AS WE RAN)
 "UBBA" .020 -.03679 1.0;
 3. 0.300;
 3. 0.45281;

Figure 5 a

```

5. "UQ9" 0.0286 2.06885 1.0;
0.300;
0.300;
0.48124;
"UQ10" 0.0286 -1.27525 1.0;
0.500;
0.500;
0.500;
0.500;
0.28386;
"UQ11" 0.0286 -0.41439 1.0;
0.300;
0.400;
0.4878;
"UQ12" 0.036 2.71707 1.0;
0.00674;
"UQ13" 0.036 2.55482 1.0;
0.10551;
"UQ14" 0.0375 -6.53737 1.0;
0.100;
0.15315;
0.4;
"UTGT" 0.0;
SENTINEL
SENTINEL

```

Figure 5 b

SEXTUPOLE EFFECTS IN 'U' LINE Below
UDS-6

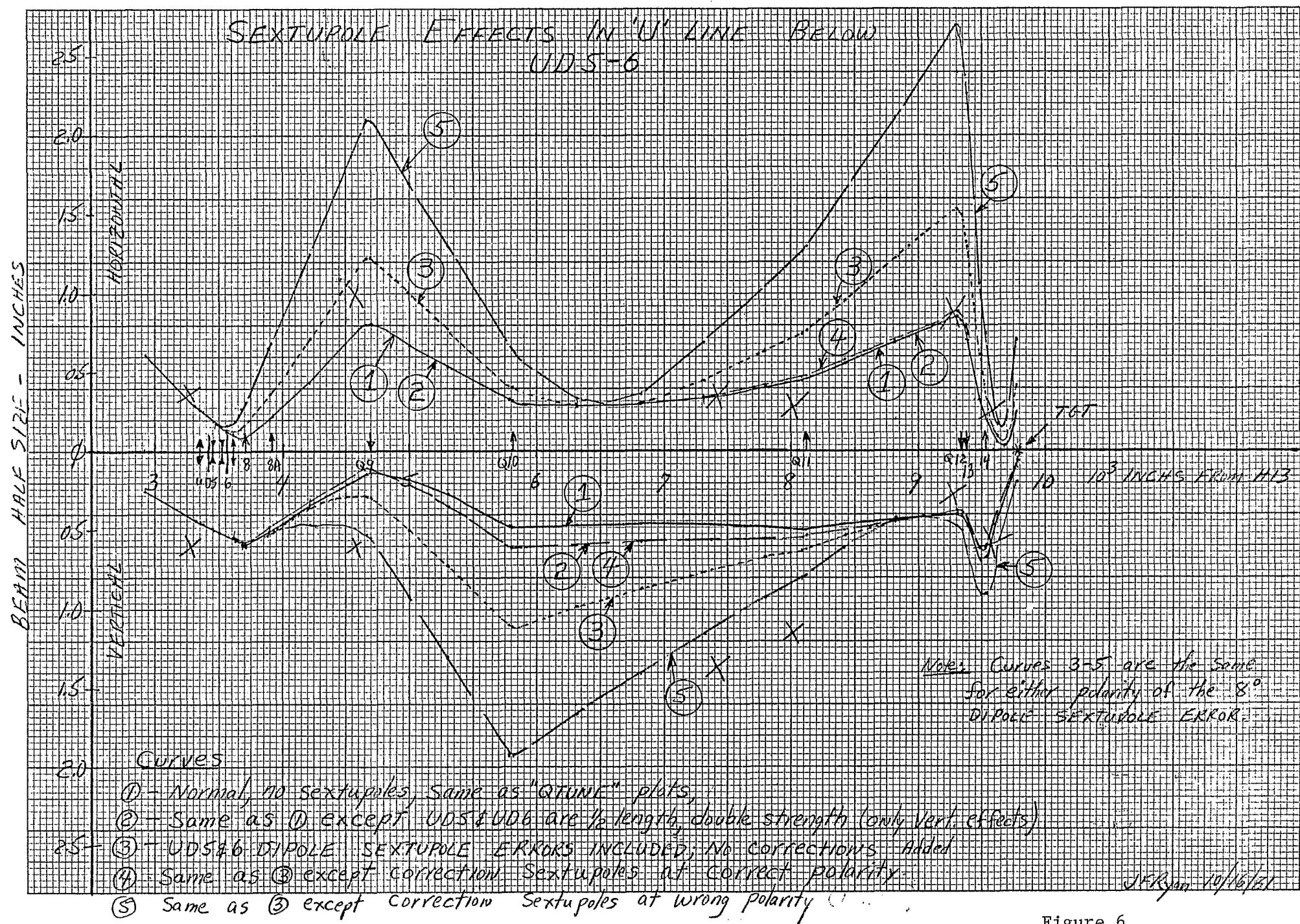
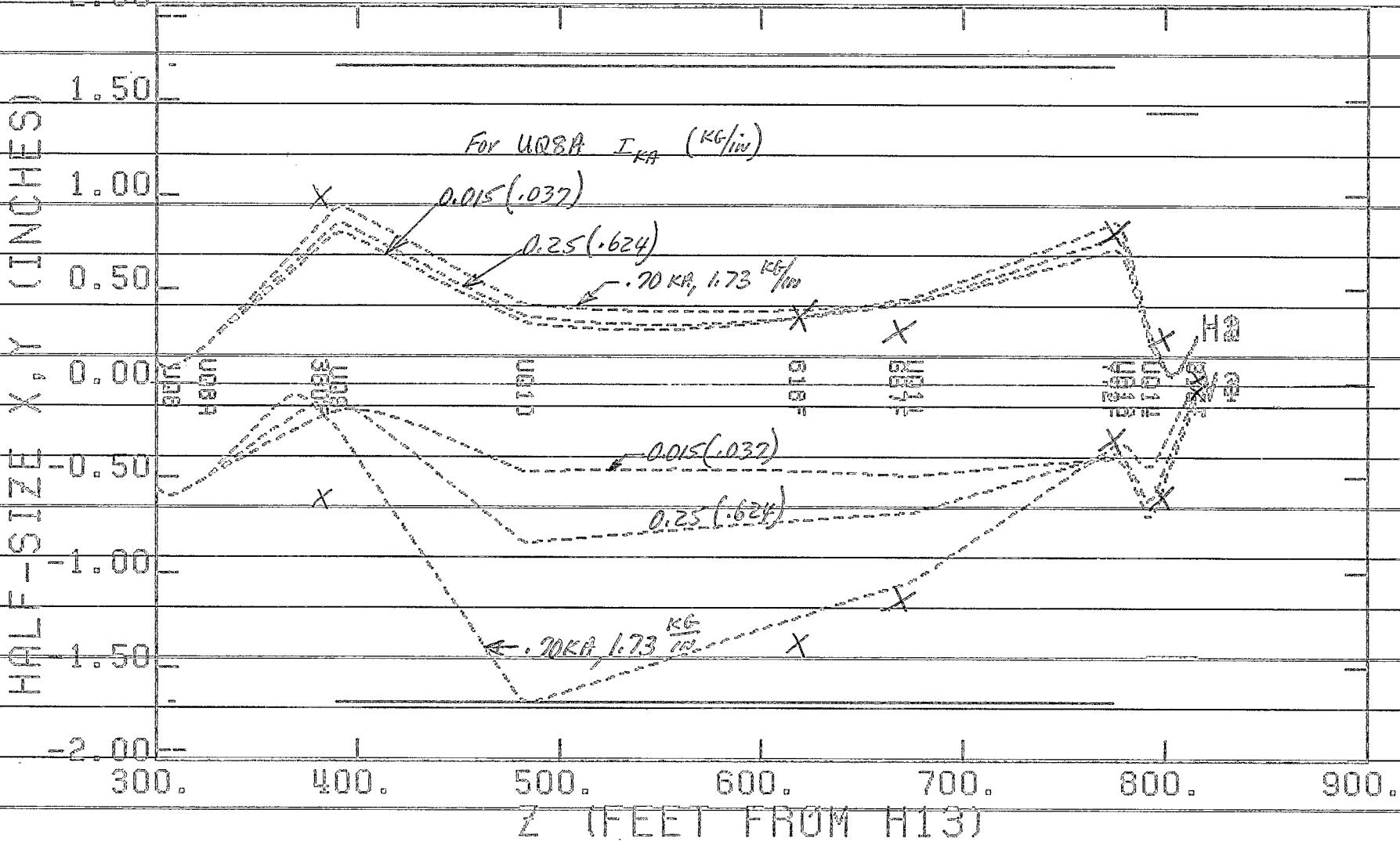


Figure 6

"U" LINE H13 TO TGT



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AGS Div. Tech. Note No. 176

EFFECT OF VARIATION CURRENT IN UG8A

Figure 7

